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Stellar Abundances in the Oldest Open Cluster: Berkeley 17

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Abstract. As part of a program of abundance studies of old open clusters, we present an analysis of high-dispersion echelle spectra of three giant stars in the 10 Gyr old cluster Berkeley 17. Abundances were determined relative to the disk giant Arcturus. Be 17 is found to have a mean [Fe/H] $= -0.10 \pm 0.05$ (mean error). Oxygen abundances, determined from the forbidden [O I] lines, show solar abundance ratios. The α-elements Mg, Ca, and Ti also show scaled solar abundance ratios, with suggestions that the Si abundance is slightly enhanced. The odd-Z elements Na and Al are significantly enhanced relative to scaled solar abundances. These abundance patterns are similar to those in two other 8-10 Gyr old open clusters, Cr261 and NGC 6791, and suggest that the Galactic disk was enriched to solar abundance levels at very early times.

Keywords. Stars:abundances, Galaxy:open clusters and associations: individual (Be 17)

1. Introduction

We are engaged in a program of study of the oldest open clusters found in the Milky Way Galaxy. These clusters enable us to probe the early history of the galactic disk, and offer useful comparisons to the behavior of field star and globular cluster populations. We present here results from the second of the clusters in our program – Berkeley 17.

Berkeley 17 is very likely the oldest open cluster known. Estimates of its age range from 7 to 12 Gyr (Phelps 1997; Kaluzny 1994; Carraro et al 1999), with the most recent estimates falling in the middle of this range at 9 to 10 Gyr. The cluster is located at a galactocentric distance of 11.2 kpc, in the direction of the Galactic anticenter. Photometric studies in BVI indicate a substantial but poorly determined reddening toward the cluster of E(B-V) ∼0.6 to 0.7 mag.

Data for 4 candidate giants drawn from the sample of Friel et al (2002) were taken at the KPNO 4-meter telescope using the echelle spectrograph. The spectra have a resolution of R ∼25,000 and a typical S/N ratio of 80 or higher. Data reduction using IRAF followed the standard procedures. Radial velocity measurements confirmed 3 stars as members of Be 17, giving an average velocity of -73.7 ± 0.08 km s^{-1} (s.d.).

2. Abundance Results

The abundance analysis followed the procedures used in the earlier work in this program as described in Friel et al (2003). Initial atmospheric parameters were derived from photometry, but values for T_{eff}, log g, and microturbulent velocity were refined using

† Any opinions, findings, and conclusions and recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

Table 1. Mean Cluster Abundances – Be 17

Element	[X/H]	σ	[X/Fe]	σ
Fe I	−0.10	0.09		
Fe II	−0.09	0.11		
Na I	+0.30	0.03	+0.40	0.10
Mg I	+0.01	0.05	+0.12	0.09
Al I	+0.15	0.03	+0.25	0.09
Si I	+0.20	0.07	+0.30	0.05
Ca I	−0.15	0.10	−0.04	0.03
Ti I	−0.20	0.03	−0.10	0.08
Ti II	+0.04	0.05	+0.14	0.07
Cr I	+0.15		+0.15	
Ni I	−0.09	0.11	+0.02	0.09
O I	−0.10	0.10	0.00	0.05

standard methods of minimizing the systematic dependences with excitation potential, ionization equilibrium and equivalent width, respectively. Abundances were derived using MOOG, adopting the line lists and atomic parameters given in Friel et al (2003), and are relative to Arcturus. Oxygen abundances were derived by synthesis of the [O I] lines at 6300Å and 6363Å, after correction for telluric contamination. More details can be found in Friel et al (2005b). Resulting mean cluster abundances are given in Table 1.

3. Conclusions

The abundance patterns of solar ratios for [O/Fe] and [α/Fe] and enhanced [Na/Fe] and [Al/Fe] seen in Be 17 are common to the majority of open clusters (Friel 2005a). The fact that these scaled solar values for oxygen and the α-elements are seen in the oldest of the clusters, with ages of 8 to 10 Gyr, indicates that the galactic disk was enriched very early on by the products of Type Ia SN, at least at the locations of these clusters. The uniformity of abundance ratios among the clusters within 4 to 5 kpc of the solar neighborhood also suggest that the enrichment proceeded similarly over these regions. However, there are now strong indications (Yong *et al.* 2005; Carney *et al.* 2005) that the outermost disk, at R_{gc} greater than ∼12–13 kpc, is enriched in oxygen and the α-elements, pointing to an episode of rapid star formation. Whether that star formation occurred in a satellite galaxy that has merged with the Milky Way, was triggered in the Milky Way by a merger, or was the result of the normal chemical evolution of the outer Galaxy, must await larger samples of clusters and field stars, and the determination of abundances for additional elements, such as the r- and s-process elements.

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